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A pilot study on health risk assessment based on body loadings of PCBs of lactating mothers at Taizhou, China, the world's major site for recycling transformers☆

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ABSTRACT

Our early study reported an extraordinarily high Estimated Daily Intake (EDI) of PCBs of lactating mothers from Taizhou, Zhejiang Province, China (based on a food consumption survey and food basket analysis). The EDI well exceeded the intake limit stipulated by FAO/WHO 70 pg TEQ/kg body weight (bw)/month. The present pilot study provided further information on PCBs body burden in lactating mothers of Taizhou. The total PCBs detected in human milk, placenta and hair samples of these lactating mothers were 363 ng/g lipid, 224 ng/g lipid, and 386 ng/g dry wt. Respectively, three times higher than those samples collected from the reference site (Lin'an). Compared with the previous reported values in the 3rd WHO coordinated study, Taizhou topped the list of 32 countries/regions with regards to WHO-PCB-TEQ values of milk samples, which could be attributed to the relatively higher level of PCB-126 derived from electronic waste. In addition, the corresponding EDI of PCBs of Taizhou mothers (12.9 pg WHO-PCB-TEQ/kg bw/day) and infants (438 pg WHO-PCB-TEQ/kg) were derived from individual congener levels in human milk. The results were also higher than the tolerable daily intakes recommended by WHO (1–4 pg WHO-TEQ/kg bw/day) by 3 and 110 times, for mothers and infants, respectively. A more intensive epidemiological study on the potential health effects of e-waste recycling activities affecting both workers and residents seems to be of top priority, based on findings of this pilot study.

1. Introduction

The rapid increase of electrical and electronic equipment waste (e-waste) has raised global concern (Chi et al., 2011; Peeranart et al., 2013). Due to deficit of well-equipped facilities and appropriate environmental regulations, and high labor costs, large amounts of discarded appliances have been exported from developed countries (mainly North America and Europe) to developing countries (Robinson, 2009). These e-waste receiving countries, usually have lower environmental standards and labour cost, which renders e-waste recycling more profitable (UNEP, 2005). China has been one of these recipient countries, receiving about 70% of global e-waste illegally imported according to the State Environmental Protection Administration of China (Xinhua Net, 2007).

Taizhou region and Guiyu town located in Zhejiang Province and Guangdong Province, respectively, are two notorious e-waste processing sites. In general, the uncontrolled recycling processes of mechanical shredding, acid leaching (outdoor) and baking (indoor) of printed circuit boards, and open combustion of plastics and wires

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(Wong et al., 2007). These e-waste recycling centers have become intensive point source, releasing a wide range of toxic chemicals. In Guiyu town, high emissions of polybrominated diphenyls ethers (PBDEs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated dibenzo-p-dioxins/furans (PCDD/DFs), and heavy metals (e.g. Cr, Cd, Cu and Pb) during uncontrolled recycling activities have brought along pollution problems and threatened the well beings of the local residents and wildlife (Leung et al., 2007; Man and Wong, 2013). In particular, Taizhou region is a major site devoted for recycling transformers and coolants, which have led to the release of polychlorinated biphenyls (PCBs), causing serious environmental and health problems (Xing et al., 2010, 2011).

Due to their long-lasting and lipophilicity characteristics, PCBs are recalcitrant to degradation and persist in animal and environmental reservoirs. Humans can expose to PCBs via inhalation, ingestion, and skin contact (WHO/EURO, 2000; Fitzgerald et al., 2004; Freels et al., 2007). Various health problems, such as dermal toxicity, immunotoxicity, endocrine effects, reproductive effects, and carcinogenicity could be associated with the exposure to PCBs (Knerr and Schrenk, 2006; Longnecker, 2015). Stored PCBs in human tissues could be transferred to the next generation, e.g. to the fetus, by means of transplacental transport (DeKoning and Karmaus, 2000), or to infants through breast-feeding (Chao et al., 2007). Govarts et al. (2012) showed that low-level exposure to PCBs could suppress fetal growth. The lower birth weight was associated with the increase of PCB-153 in cord serum (150 g per 1 μg/L) (Govarts et al., 2012).

Human milk has been used as a bioindicator in a number of real-time biomonitoring programs (e.g., Malisch and van Leeuwen, 2003; Minh et al., 2004; Turrio-Baldassarri et al., 2008; Ulaszewska et al., 2011a,b). On the other hand, placenta is an important tissue for evaluating pollutant burdens and potential adverse health effects exerted on both the mother and fetus, as a "dual" biomarker" (Chao et al., 2007). Nutrients and toxicants are transferred through placenta, which are closely connected with fetal health, and therefore placenta samples present excellent opportunities for epidemiological studies. It has been generally assumed that the transmission of persistent toxic substances (POPs) via human milk far exceeded the contribution from transmission through placenta (Matsuura et al., 2001), since the placenta might help to reduce the potential exposure of fetus to toxicants preferential screening (Iyengar and Rapp, 2001). There is an urgent need for more studies on placental transfer, in order to provide more information about their association with body burdens of PCBs.

Unlike the analyses of human milk and placenta, which are limited to lactating women, hair samples can be analyzed for any groups of populations and may be used as indicators for long-time exposure, which record accumulation of toxicants over a period of time. The use of hair for this purpose provides a number of benefits, including readily available specimens, stability, non-intrusive sampling, and ease of sample collection, transportation and storage (Covaci et al., 2002; Nakao et al., 2005).

In developed countries, PCBs have shown a declining trend in human milk in recent decades, due to the legislative regulation on the production and application of PCBs since 1974 (Konishi et al., 2001; Bates et al., 2002; Malisch and van Leeuwen, 2003). Nevertheless, there are limited studies available comparing the concentrations of PCBs in more than one matrix of the human body. There is also insufficient information research study focusing on body burdens and associated human health effects of PCBs in China (Wong et al., 2002; Hedley et al., 2006; Sun et al., 2006), especially with regards to body loadings of PCBs in workers engaged in e-waste processing activities (Zhao et al., 2006, 2007; Bi et al., 2007).

Based on the contents of PCBs in various food types collected at Taizhou region, our earlier study estimated the dietary intake of 37 PCBs of lactating mothers was 92.79 ng/kg body weight (bw)/day (Xing et al., 2011). The study involved both local residents and e-waste workers and the estimated dietary intake was derived from their daily consumption of freshwater fish (28%), meat (17%), shellfish (95), vegetables (85%), egg (4%) and marine fish (2%). The total daily intake of 9.78 pg WHO-PCB-TEQ kg bw/day far exceeded the FAO/WHO Tolerable Daily Intake (around 2.33 pg TEQ kg bw/day) (Xing et al., 2011).

The present study aims at (1) investigating PCBs loadings in human milk, placenta and hair of lactating women living or working in the Taizhou e-waste processing site, in comparison with a reference site (Lin'an, also in Zhejiang Province); (2) determining the inter-relationships between the levels of PCBs among human milk, placenta and hair; (3) identifying factors associated with PCB levels in lactating women at the study site; and (4) conducting a health risk assessment based on the PCBs levels in human body and daily intake of PCBs for these lactating women and infants.

2. Materials and methods

2.1. Sampling sites

The sampling sites have been described in Xing et al. (2011). In Zhejiang Province, Taizhou (28°40′N, 122°21′E) has been a large-scale e-waste recycling site in China, in particular, for recycling transformers and capacitors since late 1980s/early 1990s. In the southern part of Taizhou, Luqiao City was the site for executing e-waste recycling activities (Fig. 1), contributed by 40,000 people working in the e-waste recycling sector (Luqiao Government, China, 2006). In the northwest of Zhejiang Province, Lin'an (30°14′N, 119°43′E), about 245 km away from Taizhou, without electronic waste recycling activities, agriculture is the major industry, has been chosen as a reference site for comparison (Lin'an Government, china, 2006) (Fig. 1).

2.2. Sample collection

Three different types of human sample (human milk, placenta, and hair) were collected from 25 women who gave birth between August and December 2005, in both Taizhou and in Lin'an, respectively with the assistance of a local hospitals and a health center, respectively (Luqiao Hospital of Traditional Chinese Medicine, Lin'an Hospital of Traditional Chinese Medicine, and Luqiao Center for Disease Control and Prevention). Milk samples were collected within 1 week postpartum (in the hospital) by manual expression to a solvent-rinsed Pyrex bottle (100 ml) with a Teflon lined cap. Whole placentas were collected by the local gynecologists. Stainless steel scissors were used to collect the hair (~3 g) of breastfeeding mothers, located near the scalp and from the nape of the neck. Samples of placenta and hair were separately packed with aluminum foil and placed into acetone-washed reagent bottles. All human samples were kept at −20 °C until analysis. Consent forms were completed by donors before the collection of specimens. Approval for the study was obtained from the Ethics Committee of Zhejiang Provincial Center for Disease Control and Prevention.

2.3. Questionnaires

In order to study the dietary habit and personal information of the participating mothers, questionnaires derived from the second round of WHO's PCDDs, PCDFs, and PCBs exposure study with slight modifications (WHO, 1996), were completed by these donating mothers. WHO's Survey was translated from English to Simplified Chinese with some questions modified to suit the life style of Chinese living in the sampling sites. For example, for the kind of fish